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## **EMPLACEMENT GANTRY GAP ANALYSIS STUDY**

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## ACRONYMS

BSC	Bechtel SAIC, LLC
DCMIS	digital control and management information system
DOE	U.S. Department of Energy
E&R	Emplacement and Retrieval
E&R SDD	<i>Emplacement and Retrieval System Description Document</i>
ITS	important to safety
NSDB	Nuclear Safety Design Basis
SSCs	structures, systems, and components

## 1. PURPOSE AND SCOPE

To date, the project has established important to safety (ITS) performance requirements for structures, systems, and components (SSCs) based on the identification and categorization of event sequences that may result in a radiological release. These performance requirements are defined within the *Nuclear Safety Design Bases for License Application* (NSDB) (BSC 2005 [DIRS 171512], Table A-II). Further, SSCs credited with performing safety functions are classified as ITS. In turn, assurance that these SSCs will perform as required is sought through the use of consensus codes and standards.

This gap analysis is based on the design completed for license application only. Accordingly, identification of ITS SSCs beyond those defined within the NSDB are based on designs that may be subject to further development during detail design. Furthermore, several design alternatives may still be under consideration to satisfy certain safety functions, and final selection will not be determined until further design development has occurred. Therefore, for completeness, alternative designs currently under consideration will be discussed throughout this study.

This gap analysis will evaluate each code and standard identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586]) to ensure each ITS performance requirement is fully satisfied. When a performance requirement is not fully satisfied, a gap is highlighted. This study will identify requirements to supplement or augment the code or standard to meet performance requirements. Further, this gap analysis will identify nonstandard areas of the design that will be subject to a design development plan. Nonstandard components and nonstandard design configurations are defined as areas of the design that do not follow standard industry practices or codes and standards. Whereby, assurance that an SSC will perform as required may not be readily sought through the use of consensus standards.

This gap analysis is prepared by the Emplacement and Retrieval (E&R) project team and is intended for the sole use of the Engineering department in work regarding the emplacement gantry. Yucca Mountain Project personnel from the E&R project team should be consulted before use of this gap analysis for purposes other than those stated herein or by individuals other than authorized by the Engineering department.

## 2. QUALITY ASSURANCE

This document was prepared in accordance with LP-ENG-014-BSC, *Engineering Studies*. The results of this document are only to be used as the basis for the selection of applicable codes and standards and supplemental requirements and are not to be used directly to generate quality affecting products. Therefore, this engineering study is not subject to requirements of the *Quality Assurance Requirements and Description* (DOE 2004 [DIRS 171539]) document.

## 3. USE OF COMPUTER SOFTWARE

The computer software used in this study, Microsoft Word 2000, is classified as exempt from procedure LP-SI.11Q-BSC, *Software Management*. All software used to prepare this analysis is listed under Section 2.1, Software Not Subject To This Procedure, of LP-SI.11Q-BSC.

#### 4. EMPLACEMENT GANTRY FUNCTIONAL DESCRIPTION

The function of the emplacement gantry is to maneuver a waste package and its associated emplacement pallet from the bedplate of the waste package transporter, positioned at the emplacement drift transfer dock, to the final emplacement position of the waste package and pallet within the emplacement drift. To lift and move the waste package and associated waste package pallet, the gantry straddles each waste package and engages four lifting points on the waste package pallet. The same emplacement gantry can be used for waste package and pallet retrieval where the process is a reversal of emplacement.

The emplacement gantry will be an electrically powered, self-propelled, rail-based, remotely controlled gantry type crane that runs on standard 135 lb/yd crane rails with a rail center distance of 10 ft 5 in. It will be capable of operating within the emplacement drift bounding envelope and radiological and environmental conditions.

The emplacement gantry is based on nuclear crane technology and similar in concept to a straddle carrier or container loader crane. The elements of the design take proven design concepts and employ these concepts for this application. The emplacement gantry utilization is relatively low for crane industry standards. However, the operating environment is harsh due to radiation levels and ambient temperatures. Because of this environment, all emplacement gantry operations within the drift will be performed remotely and special consideration will be given to the materials of construction and reliability of components. In addition, special consideration will be given to remote recovery operations. These operations will include the ability for the equipment to maintain a safe condition and return safely to normal operations during and after a system or component failure or during or after a natural phenomenon (e.g., a seismic event).

#### 5. FUNCTIONS AND REQUIREMENTS

The following subsections will identify the ITS performance requirements credited to the emplacement gantry as stated in the NSDB (BSC 2005 [DIRS 171512], Table A-II). The individual SSCs plus their functions, indicated in the tables contained in this section, were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586]) by close inspection of all available drawings, calculations and analysis pertaining to the emplacement gantry. These SSCs and their functions are accredited with ensuring that each ITS performance requirement is fully satisfied. Also indicated within this section are the additional performance and environmental requirements linked to the SSCs and identified within the *Emplacement and Retrieval System Description Document* (E&R SDD) (BSC 2005 [DIRS 171251]). The information within these subsections will form the bases for input to the matrix contained in Appendix A of this document.

## 5.1 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 1

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 1, applicable to the emplacement gantry, states:

*The emplacement gantry shall have a drop rate of less than or equal to  $1 \times 10^{-5}$  drops/transfer regardless of the cause, including equipment failures, human error, or some combination of the two.*

### 5.1.1 Applicable ITS SSCs and their Functions

Table 1. NSDB Requirement 1 Applicable ITS SSCs and Their Functions

SSC	ITS Function
Structural Frame	<ul style="list-style-type: none"><li>• To support the waste package and pallet</li><li>• To provide support to the waste package lifting features and drive system</li><li>• To provide support to the linear travel wheels and drive system</li><li>• To provide support to all additional equipment, lights, cameras, and control systems</li></ul>
Lifting Hooks	To lift the waste package and its associated pallet
Ball Screws	To move and support the load of a waste package and pallet
Gear Boxes	To transfer the required rotational motion from the motor to the ball screws
Motors	To provide the required speed and energy to the gearboxes
Lift Brakes	To ensure, when required, that no movement of the lift drive system occurs
Drive Shafts	To transmit power and speed from the gear boxes to the ball screws
Couplings	To connect drive shafts to gear boxes and ball screws

SSCs and their functions were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586])

### 5.1.2 Additional Design Requirements

The following general and interface requirements taken from the E&R SDD (BSC 2005 [DIRS 171251]) are identified as being applicable to the SSCs listed in Table 1.

#### 5.1.2.1 Environmental and Operational Requirements (See Section 5.10)

#### 5.1.2.2 General Requirements

- Waste emplacement equipment shall emplace and retrieve waste packages of varying sizes with the maximum dimensions of 86.1 in. diameter and 236.3 in. long (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).
- Waste emplacement equipment shall emplace and retrieve waste packages of varying weights with a maximum weight of 161,000 lbs, plus the maximum weight of a long emplacement pallet, 5,500 lbs (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).

- Waste emplacement and retrieval equipment, under normal operating conditions, shall handle waste packages only by the emplacement pallet (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).
- The emplacement equipment shall operate within the 16-ft diameter working envelope of the emplacement drifts (BSC 2005 [DIRS 171251], Section 3.1.3.3.2).
- The emplacement equipment shall be designed to operate on a maximum grade of  $\pm 0.25$  percent (BSC 2005 [DIRS 171251], Section 3.1.3.3.3).
- The design of the emplacement and retrieval equipment shall allow for equipment retrieval in case of derailment, wheel failure, loss of power, or similar off-normal occurrences (BSC 2005 [DIRS 171251], Section 3.1.1.4.2).
- The maximum operating lift or hoist speed that the emplacement equipment can lift a waste package shall be no greater than 6 ft per min, as specified in ASME NOG-1 [DIRS 158891] for a slow hoist speed for a load between 70 and 99 tons (BSC 2005 [DIRS 171251], Section 3.1.2.2.1 (7)).
- The emplacement equipment shall perform a controlled nonemergency stop should onboard faults be detected (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).
- The emplacement equipment shall have the capability of detecting onboard faults (non inclusive), including data communications or failure, electrical failure, drive system failure, lift system failure, video feedback failure, and control system failure (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).

### **5.1.2.3 Applicable Interface Requirements**

- The system shall provide communication features, including video, voice, and data communications to support surface, subsurface, and transportation functions, as well as the transfer of information off site (BSC 2005 [DIRS 171251], Section 3.3.5.1.1 ).
- The system shall communicate operating conditions to the digital control management information system (DCMIS) (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- The system shall provide a visual means of observing operations (BSC 2005 [DIRS 171251], Section 3.3.5.1.2).
- The system shall provide a means of detecting operating conditions (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- Waste emplacement and retrieval equipment shall be designed so that they will not damage the waste package surfaces during normal use (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).

## 5.2 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 2

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 2, applicable to the emplacement gantry, states:

*The lift height limit for WPs in a horizontal orientation on the emplacement pallet is provided in Table C-1 in Appendix C. (Table C indicates a lift height of 6.5 feet from the bottom of the pallet to an essentially unyielding surface.)*

### 5.2.1 Applicable ITS SSCs and their Functions

Table 2. NSDB Requirement 2 Applicable ITS SSCs and Their Functions

SSC	ITS Function
Structural Frame	<ul style="list-style-type: none"><li>• To support the waste package and pallet</li><li>• To provide support to the waste package lifting features and drive system</li><li>• To provide support to the linear travel wheels and drive system</li><li>• To provide support to all additional equipment, lights, cameras, and control systems.</li></ul>
Gantry Lifting Hooks	To lift the waste package and its associated pallet
Ball Screws	To move and support the load of a waste package and pallet
Gear Boxes	To transfer the required rotational motion from the motor to the ball screws
Motors	To provide the required speed and energy to the gearboxes
Lift Brakes	To ensure, when required, that no movement of the lift drive system occurs
Drive Shafts	To transmit power and speed from the gear boxes to the ball screws
Couplings	To connect drive shafts to gear boxes and ball screws

SSCs and their functions were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586])

### 5.2.2 Additional Design Requirements

The following general and interface requirements taken from the E&R SDD (BSC 2005 [DIRS 171251]) are credited with being applicable to the SSCs listed in Table 2.

#### 5.2.2.1 Environmental and Operational Requirements (See Section 5.10)

#### 5.2.2.2 General Requirements

- Waste emplacement equipment shall emplace and retrieve waste packages of varying sizes with the maximum dimensions of 86.1 in. diameter and 236.3 in. long (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).
- Waste emplacement equipment shall emplace and retrieve waste packages of varying weights with a maximum weight of 161,000 lbs, plus the maximum weight of a long emplacement pallet, 5,500 lbs (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).

- Waste emplacement and retrieval equipment, under normal operating conditions, shall handle waste packages only by the emplacement pallet (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).
- The emplacement equipment shall operate within the 16-ft diameter working envelope of the emplacement drifts (BSC 2005 [DIRS 171251], Section 3.1.3.3.2).
- The design of the emplacement and retrieval equipment shall allow for equipment retrieval in case of derailment, wheel failure, and loss of power, or similar off-normal occurrences (BSC 2005 [DIRS 171251], Section 3.1.1.4.2 ).
- The maximum operating lift or hoist speed that the emplacement equipment can lift a waste package shall be no greater than 6 ft per min, as specified in ASME NOG-1 [DIRS 158891] for a slow hoist speed for a load between 70 and 99 tons (BSC 2005 [DIRS 171251], Section 3.1.2.2.1 (7)).

#### **5.2.2.3 Applicable Interface Requirements**

- The system shall provide communication features, including video, voice, and data communications to support surface, subsurface, and transportation functions, as well as the transfer of information off site (BSC 2005 [DIRS 171251], Section 3.3.5.1.1 ).
- The system shall communicate operating conditions to the DCMIS (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- The system shall provide a visual means of observing operations (BSC 2005 [DIRS 171251], Section 3.3.5.1.2).
- The system shall provide a means of detecting operating conditions (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- Waste emplacement and retrieval equipment shall be designed so that they will not damage the waste package surfaces during normal use (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).

### **5.3 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 3**

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 3, applicable to the emplacement gantry, states:

*The WP emplacement gantry, carrying a WP, shall not be capable of running off the end of the emplacement drift or transfer dock rails.*



### 5.3.1 Applicable ITS SSCs and their Functions

Table 3. NSDB Requirement 3 Applicable ITS SSCs and Their Functions

SSC	ITS Function
Bumpers	To provide a means of absorbing movement energy in a fault or collision condition
Removable and Fixed Rail Stops	To prevent movement of the gantry beyond the rail ends

SSCs and their functions were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586])

### 5.3.2 Additional Design Requirements

The following general and interface requirements taken from the E&R SDD (BSC 2005 [DIRS 171251]) are credited with being applicable to the SSCs listed in Table 3.

#### 5.3.2.1 Environmental and Operational Requirements (See Section 5.10)

#### 5.3.2.2 General Requirements

- Rail stops could also be installed at the end of the emplacement transfer dock to prevent the emplacement gantry from traveling off the end of the transfer dock (BSC 2005 [DIRS 171251], Section 4.1.1.6.16).
- The maximum operating speed that the emplacement equipment can travel shall be no greater than 150 ft per min (1.7 mph), as specified in ASME NOG-1 [158891] for a fast bridge speed for a load between 50 and 99 tons (BSC 2005 [DIRS 171251], Section 3.1.2.2.1 (4)).

#### 5.3.2.3 Applicable Interface Requirements

- The system shall provide communication features, including video, voice, and data communications to support surface, subsurface, and transportation functions, as well as the transfer of information off site (BSC 2005 [DIRS 171251], Section 3.3.5.1.1).
- The system shall communicate operating conditions to the DCMIS (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).

## 5.4 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 4

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 4, applicable to the emplacement gantry, states:

*If the WP emplacement gantry were to fall on the WP transporter and impact the WP, it shall not cause the WP to be breached.*

The achievement of this requirement cannot be demonstrated through the application of a code or standard. The requirement will be the basis of supplemental activities (see Section 8.4 for details).

## 5.5 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 5

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 5, applicable to the emplacement gantry, states:

*The WP emplacement gantry shall be limited to a maximum speed of 15 mph such that a collision at this speed limit shall not result in a WP breach.*

### 5.5.1 Applicable ITS SSCs and their Functions

Table 4. NSDB Requirement 5 Applicable ITS SSCs and Their Functions

SSC	ITS Function
Wheel Blocks, Wheels	To provide guidance, motion, and support for the gantry
Drive Motors	To provide the required speed and energy to the gearboxes
Drive Gearboxes	To provide the required rotational speed to the wheels
Drive Brakes	To ensure, when required, that no movement of the linear drive system occurs

SSCs and their functions were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586])

### 5.5.2 Additional Design Requirements

The following general and interface requirements taken from the E&R SDD (BSC 2005 [DIRS 171251]) are credited with being applicable to the SSCs listed in Table 4.

#### 5.5.2.1 Environmental and Operational Requirements (See Section 5.10)

#### 5.5.2.2 General Requirements

- Waste emplacement equipment shall emplace and retrieve waste packages of varying weights with a maximum weight of 161,000 lbs, plus the maximum weight of a long emplacement pallet, 5,500 lbs (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).
- The emplacement equipment shall be capable of traveling and emplacing waste packages within the full length, or a maximum of 2,651 ft (808 m), into the emplacement drifts (BSC 2005 [DIRS 171251], Section 3.1.3.3.1).
- The emplacement equipment shall operate within the 16-ft diameter working envelope of the emplacement drifts (BSC 2005 [DIRS 171251], Section 3.1.3.3.2).
- The emplacement equipment shall be designed to operate on a maximum grade of  $\pm 0.25$  percent (BSC 2005 [DIRS 171251], Section 3.1.3.3.3).
- The maximum operating speed that the emplacement equipment can travel shall be no greater than 150 ft per min (1.7 mph), as specified in ASME NOG-1 [DIRS 158891] for a fast bridge speed for a load between 50 and 99 tons (BSC 2005 [DIRS 171251], Section 3.1.2.2.1 (4)).

- The emplacement equipment shall be designed to sweep or otherwise remove rock debris of diameters less than 1 in. from the gantry rail (BSC 2005 [DIRS 171251], Section 3.1.3.3.4).
- The design of the emplacement and retrieval equipment shall allow for equipment retrieval in case of derailment, wheel failure, and loss of power, or similar off-normal occurrences (BSC 2005 [DIRS 171251], Section 3.1.1.4).

### 5.5.2.3 Applicable Interface Requirements

- The system shall provide communication features, including video, voice, and data communications to support surface, subsurface, and transportation functions, as well as the transfer of information off site (BSC 2005 [DIRS 171251], Section 3.3.5.1.1).
- The system shall communicate operating conditions to the DCMIS (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- The system shall provide a visual means of observing operations (BSC 2005 [DIRS 171251], Section 3.3.5.1.2).
- The system shall provide a means of detecting operating conditions (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- Waste emplacement and retrieval equipment, under normal operating conditions, shall handle waste packages only by the emplacement pallet (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).

## 5.6 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 6

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 6, applicable to the emplacement gantry, states:

*Upon a loss of power, the WP emplacement gantry shall be designed to stop, retain its load, and enter a locked mode; upon a restoration of power, the WP emplacement gantry shall stay in the locked mode until operator action is taken.*

### 5.6.1 Applicable ITS SSCs and their Functions

Table 5. NSDB Requirement 6 Applicable ITS SSCs and Their Functions

SSC	ITS Function
Lift Brakes	To ensure, when required, that no movement of the lift drive system occurs
Drive Brakes	To ensure, when required, that no movement of the linear drive system occurs

SSCs and their functions were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586])

## **5.6.2 Additional Design Requirements**

The following general and interface requirements taken from the E&R SDD (BSC 2005 [DIRS 171251]) are credited with being applicable to the SSCs listed in Table 5.

### **5.6.2.1 Environmental and Operational Requirements (See Section 5.10)**

#### **5.6.2.2 General Requirements**

- The emplacement equipment shall perform a controlled nonemergency stop should onboard faults be detected (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).
- The emplacement equipment shall have the capability of detecting onboard faults (non inclusive), including data communications or failure, electrical failure, drive system failure, kift system failure, video feedback failure, and control system failure (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).
- The system shall provide communication features, including video, voice, and data communications to support surface, subsurface, and transportation functions, as well as the transfer of information off site (BSC 2005 [DIRS 171251], Section 3.3.5.1.1).
- The system shall provide a visual means of observing operations (BSC 2005 [DIRS 171251], Section 3.3.5.1.2).
- The system shall provide a means of detecting operating conditions (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- The system shall communicate operating conditions to the DCMIS (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).

## **5.7 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 7**

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 7, applicable to the emplacement gantry, states:

*The conditional probability of the WP emplacement gantry having exceeded the lift height limit given that a drop occurred shall be  $10^{-4}$  or less.*

### 5.7.1 Applicable ITS SSCs and their Functions

Table 6. NSDB Requirement 7 Applicable ITS SSCs and Their Functions

SSC	ITS Function
Structural Frame	<ul style="list-style-type: none"><li>• To support the waste package and pallet</li><li>• To provide support to the waste package lifting features and drive system</li><li>• To provide support to the linear travel wheels and drive system</li><li>• To provide support to all additional equipment, lights, cameras, and control systems</li></ul>
Gantry Lifting Hooks	To lift the WP and its associated pallet
Ball Screws	To move and support the load of a waste package and pallet
Gear Boxes	To transfer the required rotational motion from the motor to the ball screws
Motors	To provide the required speed and energy to the gearboxes
Lift Brakes	To ensure when required that no movement of the lift drive system occurs
Drive Shafts	To transmit power and speed from the gear boxes to the ball screws
Couplings	To connect drive shafts to gear boxes and ball screws

SSCs and their functions were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586])

### 5.7.2 Additional Design Requirements

The following general and interface requirements taken from the E&R SDD (BSC 2005 [DIRS 171251]) are credited with being applicable to the SSCs listed in Table 6.

#### 5.7.2.1 Environmental and Operational Requirements (See Section 5.10)

#### 5.7.2.2 General Requirements

- Waste emplacement equipment shall emplace and retrieve waste packages of varying sizes, with the maximum dimensions of 86.1 in. diameter and 236.3 in. long (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).
- Waste emplacement equipment shall emplace and retrieve waste packages of varying weights with a maximum weight of 161,000 lbs, plus the maximum weight of a long emplacement pallet, 5,500 lbs (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).
- Waste emplacement and retrieval equipment, under normal operating conditions, shall handle waste packages only by the emplacement pallet (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).
- The emplacement equipment shall operate within the 16-ft diameter working envelope of the emplacement drifts (BSC 2005 [DIRS 171251], Section 3.1.3.3.1).
- The emplacement equipment shall be designed to operate on a maximum grade of  $\pm 0.25$  percent (BSC 2005 [DIRS 171251], Section 3.1.3.3.3).

- The design of the emplacement and retrieval equipment shall allow for equipment retrieval in case of derailment, wheel failure, and loss of power, or similar off-normal occurrences (BSC 2005 [DIRS 171251], Section 3.1.1.4).
- The emplacement equipment shall perform a controlled non-emergency stop should onboard faults be detected (BSC 2005 [DIRS 171251] Section 3.3.5.3.1).
- The emplacement equipment shall have the capability of detecting onboard faults (non inclusive), including data communications or failure, electrical failure, drive system failure, lift system failure, video feedback failure, and control system failure (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).

### 5.7.2.3 Applicable Interface Requirements

- The system shall provide communication features, including video, voice, and data communications to support surface, subsurface, and transportation functions, as well as the transfer of information off site (BSC 2005 [DIRS 171251], Section 3.3.5.1.1).
- The system shall communicate operating conditions to the DCMIS (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- The system shall provide a visual means of observing operations (BSC 2005 [DIRS 171251], Section 3.3.5.1.2).
- The system shall provide a means of detecting operating conditions (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- Waste emplacement and retrieval equipment shall be designed so that they will not damage the waste package surfaces during normal use (BSC 2005 [DIRS 171251], Section 3.1.3.1.5).

## 5.8 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 8

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 8, applicable to the emplacement gantry, states:

*In the event of a credible fire in an area where waste forms are present, the temperature of machinery that handles or transports SNF/HLW shall not reach a level that would make it drop its load.*

### 5.8.1 Applicable ITS SSCs and their Functions

Table 7. NSDB Requirement 8 Applicable ITS SSCs and Their Functions

SSC	ITS Function
Structural Frame	<ul style="list-style-type: none"> <li>• To support the waste package and pallet</li> <li>• To provide support to the waste package lifting features and drive system</li> <li>• To provide support to the linear travel wheels and drive system</li> </ul>

	• To provide support to all additional equipment, lights, cameras, and control systems
Lift Brakes	To ensure, when required, that no movement of the lift drive system occurs

SSCs and their functions were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586])

## 5.8.2 Additional Design Requirements

The following general and interface requirements taken from the E&R SDD (BSC 2005 [DIRS 171251]) are credited with being applicable to the SSCs listed in Table 7.

### 5.8.2.1 Environmental and Operational Requirements (See Section 5.10)

### 5.8.2.2 General Requirements

- The design of the emplacement and retrieval equipment shall allow for equipment retrieval in case of derailment, wheel failure, and loss of power, or similar off-normal occurrences (BSC 2005 [DIRS 171251], Section 3.1.1.4).
- The electrical and control enclosures installed on the emplacement and retrieval equipment shall be protected by redundant automatic fire extinguishing systems. These will detect the fire, then discharge inside the electrical and control enclosures to extinguish fires caused by electrical shorts and arcing (BSC 2005 [DIRS 171251], Section 3.3.7.1.1).
- The emplacement and retrieval system shall include a fire protection system (BSC 2005 [DIRS 171251], Section 3.3.7.1.1).
- The emplacement equipment shall perform a controlled non-emergency stop should onboard faults be detected (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).
- The emplacement equipment shall have the capability of detecting onboard faults (non inclusive), including data communications or failure, electrical failure, drive system failure, lift system failure, video feedback failure, and control system failure (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).

### 5.8.2.3 Applicable Interface Requirements

- The system shall provide communication features, including video, voice, and data communications to support surface, subsurface, and transportation functions, as well as the transfer of information off site (BSC 2005 [DIRS 171251], Section 3.3.5.1.1).
- The system shall communicate operating conditions to the DCMIS (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- The system shall provide a visual means of observing operations (BSC 2005 [DIRS 171251], Section 3.3.5.1.2).

- The system shall provide a means of detecting operating conditions (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).

## 5.9 NUCLEAR SAFETY DESIGN BASES REQUIREMENT NUMBER 9

NSDB Table A-II (BSC 2005 [DIRS 171512]), requirement number 9, applicable to the emplacement gantry, states:

*A tipover and breach of a WP due to uncontrolled movements produced by a loss of power or a spurious signal caused by a fire shall have a probability of less than  $1 \times 10^{-4}$  over the life of the facility.*

### 5.9.1 Applicable ITS SSCs and their Functions

Table 8. NSDB Requirement 9 Applicable ITS SSCs and Their Functions

SSC	ITS Function
Structural Frame	<ul style="list-style-type: none"> <li>• To support the waste package and pallet</li> <li>• To provide support to the waste package lifting features and drive system</li> <li>• To provide support to the linear travel wheels and drive system</li> <li>• To provide support to all additional equipment, lights, cameras, and control systems</li> </ul>
Lift Brakes	To ensure, when required, that no movement of the lift drive system occurs
Drive Brakes	To ensure, when required, that no movement of the linear drive system occurs

SSCs and their functions were identified within the *Emplacement Gantry ITS Standards Identification Study* (BSC 2005 [DIRS 173586])

### 5.9.2 Additional Design Requirements

The following general and interface requirements taken from the E&R SDD (BSC 2005 [DIRS 171251]) are credited with being applicable to the SSCs listed in Table 8.

#### 5.9.2.1 Environmental and Operational Requirements (See Section 5.10)

#### 5.9.2.2 General Requirements

- The emplacement equipment shall perform a controlled non-emergency stop should onboard faults be detected (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).
- The emplacement equipment shall have the capability of detecting onboard faults (non inclusive), including data communications or failure, electrical failure, drive system failure, lift system failure, video feedback failure, and control system failure (BSC 2005 [DIRS 171251], Section 3.3.5.3.1).
- The electrical and control enclosures installed on the emplacement and retrieval equipment shall be protected by redundant automatic fire extinguishing systems. These will detect the fire, then discharge inside the electrical and control enclosures to extinguish fires caused by electrical shorts and arcing (BSC 2005 [DIRS 171251], Section 3.3.7.1.1).



- The emplacement and retrieval system shall include a fire protection system (BSC 2005 [DIRS 171251], Section 3.3.7.1.1).
- The maximum operating lift or hoist speed that the emplacement equipment can lift a waste package shall be no greater than 6 ft per min, as specified in ASME NOG-1 [DIRS 158891] for a slow hoist speed for a load between 70 and 99 tons (BSC 2005 [DIRS 171251], Section 3.1.2.2.1 (7)).
- The maximum operating speed that the emplacement equipment can travel shall be no greater than 150 ft per min (1.7 mph), as specified in ASME NOG-1 [DIRS 158891] for a fast bridge speed for a load between 50 and 99 tons (BSC 2005 [DIRS 171251], Section 3.1.2.2.1 (4)).

#### **5.9.2.3 Applicable Interface Requirements**

- The system shall provide communication features, including video, voice, and data communications to support surface, subsurface, and transportation functions, as well as the transfer of information off site (BSC 2005 [DIRS 171251], Section 3.3.5.1.1).
- The system shall communicate operating conditions to the DCMIS (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).
- The system shall provide a visual means of observing operations (BSC 2005 [DIRS 171251], Section 3.3.5.1.2).
- The system shall provide a means of detecting operating conditions (BSC 2005 [DIRS 171251], Section 3.1.1.3.6).

### **5.10 ENVIRONMENTAL & OPERATIONAL DESIGN REQUIREMENTS**

Environmental and operational requirements are taken from the *Emplacement and Retrieval System Description Document* (BSC 2005 [DIRS 171251]). The following mechanical, environmental, and operational requirements are applicable to all SSCs detailed within the previous Sections 5.1 through 5.9 of this report.

- The system shall be designed to withstand and operate during the peak emplacement drift temperature of 122°F (50°C) (BSC 2005 [DIRS 171251], Section 3.2.5.3).
- The system shall operate within the emplacement drift relative humidity of 3 to 10 percent (BSC 2005 [DIRS 171251], Section 3.2.5.4).
- The system shall be designed and operated to withstand the effects of radiation and minimize radiation exposures (BSC 2005 [DIRS 171251], Section 3.2.1.1.1).
- The system shall be designed to be protected from and withstand radiation damage, to the extent practical, under normal and off-normal conditions. The dose rates for emplacement and retrieval equipment are 600.7 (Rem/hr) on the waste package radial

surface and 1,290 (Rem/hr) on the bottom lid (BSC 2005 [DIRS 171251], Section 3.2.1.1.1.).

- The system shall be capable of removing the waste packages from the emplacement drifts for transportation back to the surface facilities (BSC 2005 [DIRS 171251], Section 3.1.2.3.1).
- The system shall be designed to have an operational life of 50 years. Equipment shall satisfy this criterion directly or be maintainable or easily replaced over the system lifetime (BSC 2005 [DIRS 171251], Section 3.3.2.1.1).
- The emplacement equipment shall have a minimum design life for electronics and electrical components of two years (BSC 2005 [DIRS 171251], Section 3.2.1.3.1).
- The system design shall include provisions for decontamination and decommissioning (BSC 2005 [DIRS 171251], Section 3.3.2.1.2).
- The system shall be designed to incorporate the use of noncombustible and heat resistant materials to the extent practical (BSC 2005 [DIRS 171251], Section 3.3.2.1.3).
- The electrical and electronic enclosures located on the emplacement and retrieval equipment shall be NEMA 4X (BSC 2005 [DIRS 171251], Section 3.3.4.1.1).
- The electrical and electronic enclosures shall include features for protection against the temperatures in which the equipment operates. These features may include air conditioning units, heaters, and insulation, as required (BSC 2005 [DIRS 171251], Section 3.3.4.1.2).
- The system shall provide a visual means of observing operations (BSC 2005 [DIRS 171251], Section 3.3.5.1.2).
- The emplacement and retrieval system shall include a fire protection system (BSC 2005 [DIRS 171251], Section 3.3.7.1.1).
- Batteries used on the emplacement and retrieval equipment shall be selected to minimize hydrogen off gassing. If continuous on-board battery charging is utilized, current limiting devices shall be installed, as necessary (BSC 2005 [DIRS 171251], Section 3.3.7.1.2).
- The system shall have the capability to identify the drift and location within the drift where the waste package will be emplaced (BSC 2005 [DIRS 171251], Section 3.1.1.3.1).
- The emplacement position may be an absolute position (i.e., 256 ft into the drift) or relative (i.e., 4 in. from a previously emplaced waste package). Included in this requirement is the need for the system to know that it has moved to a particular drift for emplacement. Therefore, Performance Acceptance Criterion 2 is established so that

equipment location is detected and transmitted to the DCMIS (BSC 2005 [DIRS 171251], Section 3.1.1.3.1).

- The emplacement gantry shall be designed so it will not drop a waste package or become inoperable as a result of a Category 1 or Category 2 seismic event (BSC 2005 [DIRS 171251], Section 4.1.1.3).

## **6. APPLICABLE CODES AND STANDARDS**

Section 6 will provide the rationale for the selection of codes and standards considered applicable to the design, construction, and testing of those SSCs identified as performing an ITS function within Section 5 of this report.

The particular code and standard, or applicable sections, will provide further input to the matrix contained in Appendix A of this report.

### **6.1 ASME NOG.1 2002**

*Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)* New York, New York: American Society of Mechanical Engineers (ASME NOG-1-2002 [DIRS 158891]).

The rationale for the selection of this code and standard to the emplacement gantry structure frame is based upon the following factors:

- Quality control via endorsement of ASME NQA-1 [DIRS 159544].
- Dynamic seismic qualification adopting methodologies from U.S. Nuclear Regulatory Commission regulatory guides.
- Material controls ensuring traceability of the important material properties.
- Environmental conditions addressing requirements associated with harsh conditions, radiation, and contamination, including as low as is reasonably achievable and detrimental aging effects.
- Single failure proof includes the requirements and examples of single failure proof designs.
- Testing includes components tests, welding tests, and overall equipment tests.
- Recognition by industry. The requirements were developed and have evolved from the meetings held by the Cranes for Nuclear Facilities committee sessions attended by representatives of the U.S. Department of Energy (DOE), U.S. Nuclear Regulatory Commission, NASA, and the manufacturing industry.

Further, the emplacement gantry frame, design, construction, and testing shall be fulfilled according to the requirements of ASME NOG-1-2002 [DIRS 158891] for a Type I Crane. This selection is based upon the following definition of a Type I Crane:

**Crane, Type I**—A crane that is used to handle a critical load. It shall be designed and constructed so that it will remain in place and support the critical load during and after a seismic event, but does not have to be operational after this event. Single failure-proof features shall be included so that any *credible failure* of a single component will not result in the loss of capability to stop and hold the critical load.

**Critical Load**—Any lifted load whose uncontrolled movement or release could adversely affect any safety-related system when such a system is required for unit safety or could result in potential offsite exposure in excess of the limit determined by the purchaser.

## 6.2 CMAA 70-2000

*Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes.* Charlotte, North Carolina: Crane Manufacturers Association of America (CMAA 70-2000 [DIRS 153997]).

The rationale for the selection of this code and standard to SSCs of the emplacement gantry is based upon the scope of this code and standard that states: “*This standard covers electric overhead and gantry multiple girder cranes with top running bridge and trolley used at nuclear facilities and components of cranes at nuclear facilities.*” The specifications and information contained in this publication apply to top running bridge and gantry type multiple girder electric overhead traveling cranes. This specification is divided up as follows:

- General Specifications
- Crane Service Classification
- Structural Design
- Mechanical Design
- Electrical Equipment.

This specification is also invoked by ASME NOG-1-2002 [DIRS 158891].

## 6.3 ANSI N14.6-1993

*American National Standard for Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10000 lbs (4500 kg) or More.* American National Standards Institute. New York, New York: American National Standards Institute (ANSI N14.6-1993 [DIRS 102016]).

The rationale for the selection of this code and standard to SSCs of the emplacement gantry is based upon the scope of this code and standard that states: “*This standard sets forth requirements for the design, fabrication, testing, maintenance, and quality assurance programs for special lifting devices for containers weighing 10,000 pounds (4500 kg) or more for*

radioactive materials, and for those features of the attachment members of the container that affect the function and safety of the lift.” The standard specifically deals with the following:

- Lubricants that are subject to radiation degradation
- Design considerations to minimize decontamination efforts
- Materials of construction that avoid corrosion by decontamination processes
- Coatings of materials of construction that are not subject to radiation degradation
- Providing further considerations for testing requirements; in particular, acceptance testing.

#### **6.4 NFPA 801.2003**

*Standard for Fire Protection for Facilities Handling Radioactive Materials.* 2003 Edition. Quincy, Massachusetts: National Fire Protection Association (NFPA 801. 2003 [DIRS 165077]).

The rationale for the selection of this code and standard to SSCs of the emplacement gantry is based upon the scope of this code and standard that states: *“This standard addresses fire protection requirements intended to reduce the risk of fires and explosions at facilities handling radioactive materials. These requirements are applicable to all locations where radioactive materials are stored, handled, or used in quantities and conditions requiring government oversight and/or license (e.g., U.S. Nuclear Regulatory Commission or U.S. Department of Energy) to possess or use these materials and to all other locations with equal quantities or conditions.”*

#### **6.5 ANSI B5.48. 1977**

*Ball Screws.* New York, New York: American Society of Mechanical Engineers (ANSI B5.48. 1977 [DIRS 173582]).

The rationale for the selection of this code and standard to SSCs of the emplacement gantry is based upon the scope of this code and standard that states: *“This standard covers definitions, classes of ball screws, recommended combinations of screw diameters and leads, recommended drawing formats, and performance characteristics of ball screw and nut assemblies as applied to machine tools.”*

#### **6.6 ASME B1.5. 1997**

*Acme Screw Threads.* New York, New York: American Society of Mechanical Engineers (ASME B1.5. 1997 [DIRS 173583]).

The rationale for the selection of this code and standard to SSCs of the emplacement gantry is based upon the scope of this code and standard that states: *“This standard provides specifications, formulas, and tables. This standard provides for two general applications of*

*Acme threads: namely, general purpose and centralizing. The limits and tolerances in this standard relate to single-start Acme threads and may be used, if considered suitable, for multiple-start Acme threads. The latter threads are used to provide relatively fast traversing motion when necessary.”*

## **7. GAP ANALYSIS MATRIX (SEE APPENDIX A)**

The matrix in Appendix A provides a summary of the information given in previous sections of this report, namely:

- The NSDB safety requirement (Section 5)
- The SSCs credited with the performance of the safety requirements (Section 5)
- Identified codes and standards that will be used in the design, fabrication, testing, and installation of the SSCs (Section 6).

Where a code and standard are deficient in assuring the SSC will perform its required safety function, a gap will be highlighted in the matrix. This gap will be filled by the following:

- Supplemental Requirements—These are supplements needed to the codes and standards identified and may include additional drawings, calculations, analyses, tests, inspections, or changes in specific requirements necessary to demonstrate that an ITS SSC will perform as required. Supplemental requirements are detailed in Section 8.
- Design Development Requirements—These are development needs identified where no code and standard exist or the requirement is one of operability or reliability. Design development requirements may include drawings, calculations, analyses, or tests necessary to demonstrate that an ITS SSC will perform as required. Design development requirements are detailed in Section 9.

## **8. SUPPLEMENTAL REQUIREMENTS**

After evaluation of the codes and standards listed in Section 6, that were determined as providing assurance that identified SSCs will perform their ITS function. It may be found that the code and standard are inadequate and do not fully satisfy a requirement. This establishes a gap and is highlighted in the matrix in Appendix A. Section 8 details the supplemental requirements where necessary to the codes and standards to ensure the SSCs ITS performance requirements are fully satisfied and the gap is filled.

## 8.1 SUPPLEMENTAL REQUIREMENT 1

The gap analysis matrix in Appendix A identified that the NSDB requirement number 1 (Section 5.1) is an operational reliability requirement stating:

*The emplacement gantry shall have a drop rate of less than or equal to  $1 \times 10^{-5}$  drops/transfer.*

This operational reliability requirement cannot be demonstrated by the application of an industry code and standard or by supplemental activities to the code and standard. Therefore, the reliability of the gantry to not drop a waste package during transfer will be demonstrated by design development plan activities (Section 9.1).

The gantry structure and associated load path ITS SSCs are adequate to support the waste package and will be demonstrated by adherence to the requirements of the codes and standards selected. (See Appendix A for codes and standards applicable to the identified ITS SSCs. See Section 6 for the rationale of the selection of the code and standard.) These codes and standards adequately indicate the materials, stress levels, deflection amounts, fabrication techniques, and weld inspection procedures to be used in the design and construction of the gantry. The code and standards do not, however, detail test activities to adequately confirm the design and fabrication. The supplemental testing activities, to ensure ITS safety function requirements are achieved, are indicated in the matrix, Appendix A, and are detailed in the following sections.

### 8.1.1 Structural Frame

The codes and standards selected for the design, construction, and testing of the gantry structural frame are ASME NOG-1-2002 [DIRS 158891] and ANSI N14.6-1993 [DIRS 102016]. ASME NOG.1 [DIRS 158891] states adequate calculation procedures to ensure the structure will not exceed the stress and deflection amounts given within the code and standard. However, the code and standard is lacking in its guidance for testing.

ANSI N14.6 [DIRS 102016] gives guidance on testing, remote handling features, lubricants to withstand radiation degradation, and decontamination features. Considering the unique nature of the emplacement gantry, both codes and standards will require supplemental activities that could include, as a minimum, the following:

- 8.1.1.1 Finite Element Modeling—This activity will indicate in the design stage of the gantry that the structure fabrication will satisfy the loading requirements without compromising the requirements of maximum stress levels or exceeding deflection amounts required by the codes and standards.
- 8.1.1.2 Prototype Deflection Testing—This activity will indicate during the construction phase of the gantry that the gantry frame fabrication, when subjected to maximum loads and extreme conditions, will not exceed the maximum deflection amounts required by the codes and standards.

It may be advantageous in the design stage to include, within the finite element modeling exercise detailed above, all the components within the load path. These will include, as a minimum, the lifting hook fabrications and ball screw assemblies.

### **8.1.2 Gantry Lifting Hook Fabrications**

The codes and standards selected for the design, construction, and testing of the gantry lifting hook fabrications are ASME NOG-1-2002 [DIRS 158891] and ANSI N14.6-1993 [DIRS 102016]. ASME NOG-1-2002 [DIRS 158891] states that adequate calculation procedures to ensure the hook fabrications will not exceed the stress and deflection amounts given within the code and standard. However, the code and standard are lacking in their guidance for testing. ANSI N14.6-1993 [DIRS 102016] however, gives guidance on testing, remote handling features, lubricants to withstand radiation degradation, and decontamination features.

Considering the unique nature of the emplacement gantry, both codes and standards would require supplemental activities that will include, as a minimum, the following sections. As mentioned in Section 8.1.1, it may be advantageous to include these components within the finite element analysis described in that section.

### **8.1.3 Ball Screws**

The code and standards listed against this SSC (ASME NOG-1-2002 [DIRS 158891]) indicate requirements to be adhered to in the design and fabrication of critical items within the load path, and details of single-failure-proof features that will be incorporated in the design, fabrication, and performance of this SSC. ANSI B5.48 [DIRS 173582] indicates recommended combinations of screw diameters, to the screw lead, and performance characteristics of the lead screw. In addition, ANSI N14.6-1993 [DIRS 102016] gives guidance on lubricants to withstand radiation degradation. However, the code and standards will be supplemented by the selection of ball screws with known nuclear pedigree (i.e., used in similar nuclear applications under similar environmental conditions). The selection of a particular type, size, or configuration will be achieved by adherence to the ball screw manufacturer's recommended selection procedure, and calculations.

### **8.1.4 Gear boxes, Motors, Brakes, and Couplings**

The selected code and standard (ASME NOG-1-2002 [DIRS 158891]) adequately covers the requirements applicable to the selection of gearboxes, motors, brakes, and couplings; however, adequate performance testing requirements are not detailed. ANSI N14.6-1993 [DIRS 102016] gives guidance on lubricants to withstand radiation degradation. Both codes and standards will be supplemented by the addition of, first, the selection of the SSCs with known nuclear pedigree (i.e., used in similar nuclear applications under similar environmental conditions), followed by type, size, and duty selection by conformance to the manufacturer's recommended selection procedure and calculations.



### **8.1.5 Drive shafts**

The selected code and standard, ASME NOG-1-2002 [DIRS 158891] adequately covers the requirements applicable to stress levels and the design of drive shafts; therefore no supplemental requirements are identified.

## **8.2 SUPPLEMENTAL REQUIREMENT 2**

The gap analysis matrix in Appendix A identified that the NSDB requirement number 2 (Section 5.2) would require supplemental activities to confirm performance. The NSDB requirement number 2 states:

*The lift height limits are 6.5 ft from bottom of the pallet to an essentially unyielding flat surface, in a horizontal orientation.*

As indicated in Appendix A, this requirement will need supplemental activities to confirm performance.

### **8.2.1 Gantry Lifting system**

The gantry, not exceeding a lift height limit, will be demonstrated by the production of assembly and subassembly drawings. These drawings will indicate the physical construction of the gantry structure, and the lifting system will be such that the maximum achievable lift height is less than the NSDB requirement. These drawings may be supplemented by the use of computerized solid modeling to provide further assurance of the gantry lifting system cannot to exceed its design lift height requirement.

## **8.3 SUPPLEMENTAL REQUIREMENT 3**

The gap analysis matrix in Appendix A identified that the NSDB requirement number 3 (Section 5.3) would require supplemental activities to confirm performance. The NSDB requirement number 3 states:

*The WP emplacement gantry, carrying a WP, shall not be capable of running off the end of the emplacement drift or transfer dock rails.*

The selected code and standard (ASME NOG-1-2002 [DIRS 158891]) provides adequate guidance in the design and fabrication of the gantry bumpers and transfer dock end of travel rail stops such that they are adequate to control excess movement of the gantry. The code and standard adequately indicates the materials, stress levels, deflection levels, and fabrication techniques to be used in the design and construction of these SSCs. The code and standard does not, however, detail test activities to adequately confirm the design and fabrication and will require supplemental testing activities to ensure ITS safety function requirements are achieved. Testing activities are indicated in the matrix, Appendix A, and detailed in the following sections.

### 8.3.1 Bumpers

The selected code and standard (ASME NOG-1-2002 [DIRS 158891]) adequately covers the requirements applicable to gantry bumpers; however, adequate performance testing requirements are not detailed. Therefore, this code and standard will be supplemented by the addition of, first, the selection of these SSCs with known nuclear pedigree (i.e., used in similar nuclear applications under similar environmental conditions), followed by type, size, and duty selection by conformance to the manufacturer's recommended selection procedure and calculations.

### 8.3.2 Transfer Dock Rail Stops

The selected code and standard (ASME NOG-1-2002 [DIRS 158891]) adequately covers the procedure and calculations applicable to the design and fabrication of end of travel rail stops. In addition, computerized solid modeling may be used to verify the remote operations of placing and removing the rail stops into and out of their location features.

## 8.4 SUPPLEMENTAL REQUIREMENT 4

The gap analysis matrix in Appendix A identified that the NSDB requirement number 4 (Section 5.4) would require supplemental activities to confirm performance. The NSDB requirement number 4 states:

*If the WP emplacement gantry were to fall on the WP transporter and impact the WP, it shall not cause the WP to be breached.*

This safety requirement cannot be demonstrated by the application of an industry code and standard; therefore, the safety function requirement of the gantry not falling onto the waste package will be demonstrated by the following supplemental activities.

- By the production of drawings to demonstrate that the gantry structural configuration will not allow contact of the gantry structure to the waste package during a fall of the gantry
- By the production of calculations to indicate the structural integrity of the gantry after impact loads, generated by the gantry falling, will not cause failure of components within the lifting system
- By the production of a computerized solid model to verify interferences and clearance.

### 8.4.1 Drawings and calculations

8.4.1.1 The production of an overall gantry assembly drawing, with all components correctly proportioned and scaled, will demonstrate the positions and interfacing relationships of all major components. Where suitable, major component dimensions will be included on the drawings.

In particular the following details will be indicated within the drawings:

- The gantry frame fabrication, including the linear travel wheels correctly positioned on the emplacement dock rails.
- The lifting hook fabrications will be shown in their maximum lowered position. This is the position of the hooks while the gantry is positioned over the waste package during the waste package and pallet removal from the transporter.
- The waste package and its associated pallet positioned on the transporter bedplate. This will include the transporter being correctly positioned on its rails within the emplacement drift turn out.
- The emplacement dock rails and support structure.

The only off-normal event that may allow the gantry to fall, therefore, permitting the gantry structures to contact the waste package, will be a collapse of the emplacement dock rails or rail supporting structures with the gantry positioned over the waste package that is sat on the bedplate of the transporter. This collapse will result in the gantry falling in either a vertical direction due to the collapse of both rails and rail supports, or a rolling fall when only one rail or rail support were to collapse. The drawings will indicate the under face of the gantry lifting hooks will impact the top surface of the transporter bedplate before structural members of the gantry can contact the waste package. These drawings may be enhanced by the use of a computerized mechanical simulation program (3D solid modeling) to further demonstrate the results of the drawings.

In conjunction with these drawings, calculations will be required in support of them. The calculations will establish the impact force to the gantry lifting hook fabrications and resulting forces that are transmitted into the various components in the lifting system, primarily the ball screw assemblies. These calculations will indicate that these forces will not cause a collapse or failure of the lifting system.

## 8.5 SUPPLEMENTAL REQUIREMENT 5

The gap analysis matrix in Appendix A identified that the NSDB requirement number 5 (Section 5.5) would require supplemental activities to confirm performance. The NSDB requirement number 5 states:

*The WP emplacement gantry shall be limited in to a maximum speed of 15 mph such that a collision at this speed limit shall not result in a WP breach.*

The code and standard selected for the design, construction, and testing of the gantry drive and associated braking system (ASME NOG-1-2002 [DIRS 158891]) gives adequate design and performance criteria applicable to satisfying the speed requirement. In addition, the code and standard provides a recommended speed of 150 ft per minute (1.7 miles per hour) for loads in excess of 90 tons (ASME NOG-1-2002 [DIRS 158891]). This recommended speed is lower than the NSDB requirements maximum speed. However, testing activities are not adequately dealt with within the code and standard; therefore, it will require supplemental testing activities that will include, as a minimum, the following.

### 8.5.1 Gear Boxes, Motors, and Brakes

The selected code and standard (ASME NOG-1-2002 [DIRS 158891]) adequately covers the requirements applicable to the selection of gearboxes, motors, brakes, and couplings; however, adequate performance testing requirements are not detailed. ANSI N14.6 [DIRS 102016] gives guidance on lubricants to withstand radiation degradation. These codes and standards will be supplemented by the addition of, first, the selection of the SSCs with known nuclear pedigree (i.e., used in similar nuclear applications under similar environmental conditions), followed by type, size, and duty selection by conformance to the manufacturer's recommended selection procedure and calculations.

## 8.6 SUPPLEMENTAL REQUIREMENT 6

The gap analysis matrix in Appendix A identified that the NSDB requirement number 6 (Section 5.6) would require supplemental activities to confirm performance. The NSDB requirement number 6 states:

*Upon a loss of power, the WP emplacement gantry shall be designed to stop, retain the load, and enter a locked mode; upon a restoration of power, the WP emplacement gantry shall stay in the locked mode until operator action is taken.*

The code and standard selected for the design, construction, and testing of the two gantry drives and their associated braking systems (ASME NOG-1-2002 [DIRS 158891]) gives adequate design and performance criteria applicable to satisfying the motor power circuit disconnecting devices that could ensure this requirement is achieved. However, testing activities are not adequately dealt with within the code and standard; therefore, this would require supplemental testing activities that will include, as a minimum, the following.

### 8.6.1 Gear boxes, Motors, Brakes, and Couplings

The selected code and standard (ASME NOG-1-2002 [DIRS 158891]) adequately covers the requirements applicable to the selection of gearboxes, motors, brakes, and couplings; however, adequate performance testing requirements are not detailed. ANSI N14.6 [DIRS 102016] gives guidance on lubricants to withstand radiation degradation. These codes and standards will be supplemented by the addition of, first, the selection of these SSCs with known nuclear pedigree (i.e., used in similar nuclear applications under similar environmental conditions), followed by type, size, and duty selection by conformance to the manufacturer's recommended selection procedure and calculations.

## 8.7 SUPPLEMENTAL REQUIREMENT 7

The gap analysis matrix in Appendix A identified that NSDB requirement number 7 (Section 5.7) is an operational reliability requirement that states:

*The conditional probability of the WP emplacement gantry having exceeded the lift height limit given that a drop occurred shall be  $10^{-4}$  or less.*

This operational reliability requirement cannot be demonstrated by the application of an industry code and standard or by supplemental activities to the code and standard. Therefore, the reliability of the gantry to not drop a waste package during transfer will be demonstrated by design development plan activities. See Section 9.7 for details.

## **8.8 SUPPLEMENTAL REQUIREMENT 8**

The gap analysis matrix in Appendix A identified that the NSDB requirement number 8 (Section 5.8) would require supplemental activities to confirm performance. The NSDB requirement number 8 states:

*In the event of a credible fire in an area where waste forms are present, the temperature of machinery that handles or transports SNF/HLW shall not reach a level that would make it drop its load.*

The gantry structure and associated load path ITS SSCs are adequate to support the waste package and will be demonstrated by adherence to the requirements of the codes and standards selected. (See Appendix A for codes and standards applicable to the identified ITS SSCs and Section 6 for the rationale of the selection of the code and standard.) They adequately indicate the materials, stress levels, deflection levels, and fabrication techniques to be used in the design and construction of the gantry.

In addition, the code and standard selected for the design, construction, and testing of the gantry control systems (ASME NOG-1-2002 [DIRS 158891]) gives adequate design and performance criteria applicable to satisfying motor power circuit disconnecting devices. These would ensure that during an off-normal event, the requirement will be achieved by bringing the gantry to a controlled stop and applying both the linear drive and lift drive brakes. However, testing activities are not adequately dealt with within the code and standard; therefore, this will require supplemental testing activities that will include, as a minimum, the bench testing of both systems to verify that performance requirements are achieved. The application of NFPA 801.2003 [DIRS 165077] will also ensure that adequate fire detection and suppression systems will be incorporated into the design that provides further assurance that the requirement will be achieved.

## **8.9 SUPPLEMENTAL REQUIREMENT 9**

The gap analysis matrix in Appendix A identified that NSDB requirement number 9 (Section 5.9) is an operational reliability requirement that states:

*A tipover and breach of a Waste Package while on machinery that handles or transports SNF/HLW due to uncontrolled movements produced by a loss of power or a spurious signal caused by a fire shall have a probability of less than  $1 \times 10^{-5}$  over the life of the facility.*

This operational reliability requirement cannot be demonstrated by the application of an industry code and standard or by supplemental activities to the code and standard. Therefore, the reliability of the gantry to not drop a waste package during transfer will be demonstrated by design development plan activities. See Section 9.9 for details.

## 9. DESIGN DEVELOPMENT REQUIREMENTS

If it is identified within Appendix A of this report that a particular ITS performance requirement cannot be fully satisfied by the application of a code and standard or supplemental activities, for example, a probability requirement, then the ITS performance requirement will be the subject of design development activities. A brief summary of these activities is stated below, and precise details are given in the *Emplacement gantry Design Development Plan* (BSC 2005 [DIRS 173283]).

### 9.1 DESIGN DEVELOPMENT REQUIREMENT NUMBER 1

NSDB Requirement number 1 states.

*The emplacement gantry shall have a drop rate of less than or equal to  $1 \times 10^{-5}$  drops/transfer regardless of the cause, including equipment failures, human error, or some combination of the two.*

This operational reliability requirement cannot be demonstrated by the application of an industry code and standard or supplemental activities to the code and standard. Therefore, the reliability of the gantry to not drop a waste package during transfer will be demonstrated by the following Design Development Plan activities to all load path SSCs:

- General assembly and subassembly drawings
- Failure mode and effect analysis
- Fault tree analysis
- Individual SSC bench testing
- Full scale prototype testing.

### 9.2 DESIGN DEVELOPMENT REQUIREMENT NUMBER 2

NSDB Requirement number 2 states.

*The lift height limit for WPs in a horizontal orientation on the emplacement pallet is provided in Table C-1 in Appendix C. (Table C indicates a lift height of 6.5 feet from the bottom of the pallet to an essentially unyielding surface).*

There are no identified design development activities associated with this NSDB requirement.

### 9.2 DESIGN DEVELOPMENT REQUIREMENT NUMBER 3

NSDB Requirement number 3 states.

*The WP emplacement gantry, carrying a WP, shall not be capable of running off the end of the emplacement drift or transfer dock rails.*

There are no identified design development activities associated with this NSDB requirement.

### **9.3 DESIGN DEVELOPMENT REQUIREMENT NUMBER 4**

NSDB Requirement number 4 states.

*If the WP emplacement gantry were to fall on the WP transporter and impact the WP, it shall not cause the WP to be breached.*

There are no identified design development activities associated with this NSDB requirement.

### **9.4 DESIGN DEVELOPMENT REQUIREMENT NUMBER 5**

NSDB Requirement number 5 states.

*The WP emplacement gantry shall be limited in to a maximum speed of 15 mph such that a collision at this speed limit shall not result in a WP breach.*

There are no identified design development activities associated with this NSDB requirement.

### **9.5 DESIGN DEVELOPMENT REQUIREMENT NUMBER 6**

NSDB Requirement number 6 states.

*Upon a loss of power, the WP emplacement gantry shall be designed to stop, retain its load, and enter a locked mode; upon a restoration of power, the WP emplacement gantry shall stay in the locked mode until operator action is taken.*

There are no identified design development activities associated with this NSDB requirement.

### **9.6 DESIGN DEVELOPMENT REQUIREMENT NUMBER 7**

NSDB Requirement number 7 states.

*The conditional probability of the WP emplacement gantry having exceeded the lift height limit given that a drop occurred shall be  $10^{-4}$  or less.*

This operational reliability requirement cannot be demonstrated by the application of an industry code and standard or supplemental activities to the code and standard. Therefore, the reliability of the gantry to not drop a waste package during transfer will be demonstrated by the following Design Development Plan activities:

- General assembly and subassembly drawings
- Failure mode and effect analysis
- Fault tree analysis
- Individual SSC bench testing
- Full scale prototype testing.

## 9.7 DESIGN DEVELOPMENT REQUIREMENT NUMBER 8

NSDB Requirement number 8 states.

*In the event of a credible fire in an area where waste forms are present, the temperature of machinery that handles or transports SNF/HLW shall not reach a level that would make it drop its load.*

There are no identified design development activities associated with this NSDB requirement.

## 9.8 DESIGN DEVELOPMENT REQUIREMENT NUMBER 9

NSDB Requirement number 9 states.

*A tipover and breach of a WP due to uncontrolled movements produced by a loss of power or a spurious signal caused by a fire shall have a probability of less than  $1 \times 10^{-4}$  over the life of the facility.*

This operational reliability requirement cannot be demonstrated by the application of an industry code and standard or supplemental activities to the code and standard. Therefore, the reliability of the gantry to not drop a waste package during transfer will be demonstrated by the following Design Development Plan activities:

- General assembly and subassembly drawings
- Computerized mechanical simulation (solid modeling)
- Failure mode and effect analysis
- Fault tree analysis
- Individual SSC bench testing
- Full scale prototype testing.



## 10. REFERENCES

### 10.1 DOCUMENTS CITED

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- 171512 BSC (Bechtel SAIC Company) 2005. *Nuclear Safety Design Bases for License Application*. 000-30R-MGR0-00400-000-001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050308.0004.
- 171539 DOE (U.S. Department of Energy) 2004. *Quality Assurance Requirements and Description*. DOE/RW-0333P, Rev. 16. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20040907.0002.
- 173283 BSC (Bechtel SAIC Company). 2005. *Waste Package Emplacement Gantry Design Development Plan*. 800-30R-HE00-00500-000-000. Las Vegas, Nevada: Bechtel SAIC Company.
- 173586 BSC (Bechtel SAIC Company) 2005. *Emplacement Gantry ITS Standards Identification Study*. 800-30R-HE00-00200-000-001. Las Vegas, Nevada: Bechtel SAIC Company.

### 10.2 CODES AND STANDARDS

- 102016 ANSI N14.6-1993. *American National Standard for Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10000 Pounds (4500 kg) or More*. New York, New York: American National Standards Institute. TIC: 236261.
- 153997 CMAA 70-2000. *Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes*. Charlotte, North Carolina: Crane Manufacturers Association of America. TIC: 249445.
- 158891 ASME NOG-1-2002. 2002. *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)*. New York, New York: American Society of Mechanical Engineers. TIC: 252907.
- 159544 ASME NQA-1-2000. 2001. *Quality Assurance Requirements for Nuclear Facility Applications*. New York, New York: American Society of Mechanical Engineers. TIC: 253110.
- 165077 NFPA 801. 2003. *Standard for Fire Protection for Facilities Handling Radioactive Materials*. 2003 Edition. Quincy, Massachusetts: National Fire Protection Association. TIC: 254811.

173582 ANSI B5.48. 1977. *Ball Screws*. New York, New York: American Society of Mechanical Engineers.

173583 ASME B1.5. 1997. *Acme Screw Threads*. New York, New York: American Society of Mechanical Engineers.

LP-ENG-014-BSC, Rev. 0, ICN 2. *Engineering Studies*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20040225.0003.

LP-SI.11Q-BSC, Rev. 0, ICN 1. *Software Management*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20041005.0008.

**APPENDIX A**  
**GAP ANALYSIS MATRIX**

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Table A-1. Appendix A

SDD ITS Requirements & Engineering Solutions			Code and Standard Applicability						Supplemental Requirements				Design Development Requirements				Remarks	
Requirement Number	Requirement Text	Applicable SSCs	Code or Standard (see section 6 for definitions)	Applicable Section	Section Description	Req'd Calculation	Req'd Modeling	Req'd Testing	Additional Criteria	Req'd Drawings or Calculation	Req'd Modeling	Req'd Testing	Req'd Analysis	Req'd Drawings or Calculations	Req'd Modeling	Req'd Testing		
7.1	The emplacement gantry shall have a drop rate of less than or equal to $1 \times 10^{-6}$ drops/transfer. (Reference, Nuclear Safety Design Basis for Licence Application, 000-30R-MGR0-00400-000-001, Appendix A table A-1f).	All SSCs below		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FMEA, and Fault Tree Analysis	Gantry general assembly drawing	N/A	Prototype testing and bench testing	The prototype testing will include the whole gantry assembly. Therefore by default all individual ITS SSCs will be subject to prototype testing to ensure reliability.
		Gantry Structural Support	Gantry Structure Frame	ASME NOG-1	Section 4000	Requirements for Structural Components	Design calculations in accordance with the code and standard and particularly the requirements for Gantry frame deflections	N/A	No testing details in this code and standard applicable to gantry structures. But weld testing of the fabrication is detailed	N/A	Finite Element Modeling (see section 8.1.1 for details)	Frame deflection, see section 8.1.1 for details	N/A	N/A	N/A	N/A		
					Section 4345	Gantry Frame Deflection												
				ANSI N14.6	Entire													
		Gantry Lifting system	GantryLifting Hooks	ASME NOG-1	Section 4000	Requirements for Structural Components	Design calculations in accordance with the code and standard and particularly the requirements for Gantry frame deflections	N/A	No testing details in this code and standard applicable to gantry structures. But weld testing of the fabrication is detailed	N/A	Finite Element Modeling (see section 8.1.2 for details)	Hook fabrication deflection, see section 8.1.2 for details	N/A	N/A	N/A	N/A		
					Section 7000	Required Inspections or tests												
				ANSI N14.6	Entire													
		Ball Screws		ASME NOG-1	Section 5150	Critical items	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in either of these codes and standards	N/A	Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A			
					Section 5416	Single Failure Proof features												
				ANSI B5.48 1977	Entire	Ball-Screws												
				ANSI N14.6	Entire													
		Gear boxes		ASME NOG-1	Section 5150	Critical items	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in either of these codes and standards	N/A	Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A			
					Sections 5413 & 5416	Single Failure Proof features and gearing												
				ANSI N14.6	Entire													
		Motors		ASME NOG-1	Section 5150	Critical items	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard	N/A	Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A			
					Section 5412 & 5416	Single Failure Proof features and Drive motors												
		Lift system Brakes		ASME NOG-1	Section 5150	Critical items	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard	N/A	Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A			
					Section 5414 and 5416	Single Failure Proof features and Brakes												
		Drive Shafts		ASME NOG-1	Section 5150	Critical items	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard	N/A	N/A	N/A	N/A	N/A	N/A			
					Sections 5416, 5454 and B5476	Single Failure Proof features and Drive shafts												
		Couplings		ASME NOG-1	Section 5150	Critical items	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard	N/A	Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A			
					Section 5141, 5416 and 5451	Single Failure Proof features Mech. Components and couplings												
		Gantry Lifting Control System	Limit Switches - Height	ASME NOG-1	Section 6440 including 6442, 6443, 6444 and 6445	Limit Switches, including, High, Low, Overspeed and Hoist Load Limit	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard	N/A	N/A	N/A	Limit switch performance testing to confirm operational requirements are achieved (See also section 9.1)	N/A	N/A	N/A	N/A	The limit switches are not ITS because the lift height is mechanically controlled by the construction of the gantry lift system and the gantry structure.
			Lift Drive - Controller	ASME NOG-1	Section 6410 and 5331	Controllers and Hoist speed	Selection in accordance with the stated codes and standards guidelines	Performance speed and speed tolerance calculations required in accordance to the code and standard	No applicable testing details in this code and standard	N/A	N/A	N/A	Control system performance testing to confirm operational requirements are achieved (See also section 9.1)	N/A	N/A	N/A	N/A	The Gantry control system is not ITS because the lift and travel drives will both contain "powered off" braking systems. Upon loss of power the brakes in both systems will be automatically applied. Upon recovery of power the brakes will require to be manually reset to disengage them.

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Table A-1. Appendix A (Continued)

SDD ITS Requirements & Engineering Solutions			Code and Standard Applicability						Supplemental Requirements				Design Development Requirements				Remarks		
Requirement Number	Requirement Text	Applicable SSCs	Code or Standard (see Table A-1 for definitions)	Applicable Section	Section Description	Req'd Calculation	Req'd Modeling	Req'd Testing	Additional Criteria	Req'd Drawings or Calculation	Req'd Modeling	Req'd Testing	Req'd Analysis	Req'd Drawings or Calculations	Req'd Modeling	Req'd Testing			
7.2	The lift height limits are: 6.5 ft from bottom of the horizontal orientation. (Reference, Nuclear Safety Design Basis for Licence Application, 000-30R-MGRD, 00400-000-001c, Appendix A table A-II).	All SSCs below	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	The SSCs identified as performing this safety function are not subject to the design development activities although they are not indicated here.		
		Gantry Structural Support	Gantry Structure Frame	ASME NOG-1	Section 4000	Requirements for Structural Components	Design calculations in accordance with the code and standard, particularly the requirements for Gantry frame deflections		No testing details in this code and standard applicable to gantry structures. But weld testing of the fabrication is detailed in this code and standard gives on testing but will require supplementation.		N/A	Gantry General assembly drawing	Finite Element Modeling (see section 8.1.1 for details), and Computerized simulation program (solid modeling) (see section 8.2.1)	Frame deflection, see section 8.1.1 for details	N/A	N/A	N/A		
				Section 4345	Gantry Frame Deflection														
		Gantry Lifting system	Gantry/Lifting Hooks	ASME NOG-1	Section 4000	Requirements for Structural Components	Design calculations in accordance with the code and standard, particularly the requirements for Gantry frame deflections		No testing details in this code and standard applicable to gantry structures. But weld testing of the fabrication is detailed in this code and standard gives on testing but will require supplementation.		N/A	Gantry General assembly drawing	Finite Element Modeling (see section 8.1.1 for details), and Computerized simulation program (solid modeling) (see section 8.2.1)	Hook fabrication deflection, see section 8.1.2 for details	N/A	N/A	N/A		
				Section 7000	Required Inspections or tests														
		Ball Screws	Ball Screws	ASME NOG-1	Section 5150	Critical Items			No applicable testing details in either of these codes and standards	Selection of components with a pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A		Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A		
				Section 5416	Single Failure Proof features														
		Gear boxes	Gear boxes	ANSI B5.4B 1977	Entire	Ball-Screws				No testing details in this code and standard gives on testing but will require supplementation.									
				ANSI N14.5	Entire														
		Motors	Motors	ASME NOG-1	Section 5150	Critical Items				No testing details in this code and standard gives on testing but will require supplementation.	Selection of components with a pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A		Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A	
				Section 5413 & 5416	Single Failure Proof features and gearing														
		Lift system Brakes	Lift system Brakes	ASME NOG-1	Section 5150	Critical Items				No applicable testing details in this code and standard	Selection of components with a pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A		Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A	
				Section 5412 & 5416	Single Failure Proof features and Drive motors														
		Drive Shafts	Drive Shafts	ASME NOG-1	Section 5150	Critical Items				No applicable testing details in this code and standard	Selection of components with a pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A		Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A	
				Section 5414 and 5416	Single Failure Proof features and Brakes														
		Couplings	Couplings	ASME NOG-1	Section 5150	Critical Items				No applicable testing details in this code and standard	Selection of components with a pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A		Finite Element Modeling (see section 8.1.1 for details)	N/A	N/A	N/A	N/A	
				Section 5411, 5416 and 5451	Single Failure Proof features Mech. Couplings and couplings														
		Limit Switches - Height	Limit Switches - Height	ASME NOG-1	Section 6440 including 6443, 6444 and 6445	Limit Switches, including, High, Low, Overspeed and Host Load Limit				No applicable testing details in this code and standard	Selection of components with a pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A		Limit switch performance testing to confirm operational requirements are achieved (See also section 9.1)	N/A	N/A	N/A	N/A	The limit switches are not ITS because the lift height is mechanically controlled by the construction of the gantry lift system and the gantry structure.
		Lift Drive - Controller	Lift Drive - Controller	ASME NOG-1	Section 6410 and 5331	Controllers and Host speed				No applicable testing details in this code and standard	Selection of components with a pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A		Control system performance testing to confirm operational requirements are achieved (See also section 9.1)	N/A	N/A	N/A	N/A	The Gantry control system is not ITS because the lift and travel drives will both contain "powered off" braking systems. Upon loss of power the brakes in both systems will be automatically applied. Upon recovery power the brakes will require to be manually reset (disengage them).

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Table A-1. Appendix A (Continued)

SDD ITS Requirements & Engineering Solutions			Code and Standard Applicability						Supplemental Requirements				Design Development Requirements				Remarks																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
Requirement Number	Requirement Text	Applicable SSCs	Code or Standard (see section 6 for definitions)	Applicable Section	Section Description	Req'd Calculation	Req'd Modeling	Req'd Testing	Additional Criteria	Req'd Drawings or Calculation	Req'd Modeling	Req'd Testing	Req'd Analysis	Req'd Drawings or Calculations	Req'd Modeling	Req'd Testing																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
7.3	The WP emplacement gantry, carrying a WP, shall not be capable of running off the end of the emplacement drift or transfer dock rails. (Reference, Nuclear Safety Design Basis for Licence Application, 000-30R-MGR0-00400-000-001c, Appendix A table A-1f).	Gantry Drive Control System	All SSCs below	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	The limit switches are not ITS because the linear travel is mechanically controlled by the transfer dock end of rail stops and the gantry bumpers structure.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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7.4	If the WP emplacement gantry were to fall on the WP transporter and impact the WP, it shall not cause the WP to be breached (Reference, Nuclear Safety Design Basis for Licence Application, 000-30R-MGR0-00400-000-001c, Appendix A table A-1f).	Gantry Structure	Transfer Dock	Fixed rail stops - see remarks.	Trolley Stops	Rail stop sizing calculations	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	The rail stops at the end of the emplacement dock will require to be remotely removable and replaceable to allow removal and installation of the gantry from the transporter. This will be demonstrated during testing																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
7.5	The WP emplacement gantry shall be limited in to a maximum speed of 15 mph such that a collision at this speed limit shall not result in a WP breach. (Reference, Nuclear Safety Design Basis for Licence Application, 000-30R-MGR0-00400-000-001c, Appendix A table A-1f).	Gantry Drive System	All SSCs below	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	The speed controller is not ITS because the drive system is mechanically limited to a safe velocity that cannot breach the mechanical stops.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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Table A-1. Appendix A (Continued)

SDD ITS Requirements & Engineering Solutions				Code and Standard Applicability						Supplemental Requirements				Design Development Requirements				Remarks
Requirement Number	Requirement Text	Applicable SSCs		Code or Standard (see section 6 for definitions)	Applicable Section	Section Description	Req'd Calculation	Req'd Modeling	Req'd Testing	Additional Criteria	Req'd Drawings or Calculation	Req'd Modeling	Req'd Testing	Req'd Analysis	Req'd Drawings or Calculations	Req'd Modeling	Req'd Testing	
7.6	Upon a loss of power, the WP emplacement gantry shall be designed to stop, retain the load, and enter a locked mode; upon a restoration of power, the WP emplacement gantry shall stay in the locked mode until operator action is taken. . (Reference, Nuclear Safety Design Basis for Licence Application, 000-30R-MGRD-00400-000-001c, Appendix A table A-II).	Lift system Brakes		ASME NOG-1	Section 5150	Critical items	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard	Selection of components with a reliable nuclear pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
					Section 5414 and 5416	Single Failure Proof features and Brakes												
				Drive Brakes		ASME NOG 1	Section 5443	Bridge Brakes	Design calculations in accordance with the code and standard to verify conformance	N/A	No applicable testing details in this code and standard	Selection of components with a reliable nuclear pedigree and selection calculations to suppliers information and see section 8.1 for details	Gantry General assembly drawing	N/A	Factory acceptance testing. This testing could be included with DDP testing for requirement 4	N/A	N/A	N/A
		Gantry Control System	Lift and Linear Drive Control Systems	ASME NOG 1 See remarks	Section 6432.3	Motor power circuit dis-connecting device	Design calculations in accordance with the code and standard to verify conformance	N/A	No applicable testing details in this code and standard	Selection of components with a reliable nuclear pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A	N/A	Control system performance testing to confirm operational requirements are achieved	N/A	N/A	N/A	N/A	The Gantry control system is not ITS because the lift and travel drives will both contain "powered off" braking systems. Upon loss of power the brakes in both systems will be automatically applied. Upon recovery of power the brakes will require to be manually reset to disengage them.

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Table A-1. Appendix A (Continued)

SDD ITS Requirements & Engineering Solutions			Code and Standard Applicability						Supplemental Requirements				Design Development Requirements				Remarks		
Requirement Number	Requirement Text	Applicable SSCs	Code or Standard (see section 6 for definitions)	Applicable Section	Section Description	Req'd Calculation	Req'd Modeling	Req'd Testing	Additional Criteria	Req'd Drawings or Calculation	Req'd Modeling	Req'd Testing	Req'd Analysis	Req'd Drawings or Calculations	Req'd Modeling	Req'd Testing	Remarks		
7.7	The conditional probability of the WP emplacement gantry having exceeded the lift height limit given that a Nuclear Safety Design Basis for Licence Application, 800-SDR-MGRD-000-000-001C, Appendix A Table A.10, is not exceeded, shall be 10 <sup>-4</sup> or less. (Reference, 800-SDR-MGRD-000-000-001C, Appendix A Table A.10.)	All SSCs below	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FMEA, and Fault Tree Analysis	Gantry general assembly drawing	N/A	N/A	Prototype testing and bench testing	The prototype testing will include the whole gantry. Testing by default all individual ITS SSCs will be subject to prototype testing to ensure reliability	
			Gantry Structural Support	ASME NOG-1	Section 4000	Requirements for Structural Components	Design calculations in accordance with standard and particularly the requirements for Gantry frame deflections	N/A	No testing details in this code and standard applicable to gantry structures. But weld testing of the gantry frame is detailed in this code and standard. Gantry frame testing but will require supplemental.	N/A	N/A	Finite Element Modeling (see section 8.1.1 for details), and Computerized simulation program (solid modeling) (see section 8.2.1)	N/A	N/A	N/A	N/A	N/A	N/A	
					Section 4345	Gantry Frame Deflection		N/A											
		Gantry Lifting system	ASME NOG-1	Section 4000	Requirements for Structural Components	Design calculations in accordance with standard and particularly the requirements for Gantry frame deflections	N/A	No testing details in this code and standard applicable to gantry structures. But weld testing of the fabrication is detailed in this code and standard. Gantry frame testing but will require supplemental.	N/A	N/A	Finite Element Modeling (see section 8.1.1 for details), and Computerized simulation program (solid modeling) (see section 8.2.1)	N/A	N/A	N/A	N/A	N/A	N/A		
				Section 7000	Required Inspections or tests		N/A												
		Ball Screws	ANSI N14.6	Entire					This code and standard gives no testing but will require supplemental.	N/A	N/A	Hook fabrication deflection, see section 8.1.2 for details	N/A	N/A	N/A	N/A	N/A	N/A	
				Section 5150	Critical Items				No applicable testing details in either of these codes and standards										
			ASME NOG-1	Section 5416	Single Failure Proof features	Selection in accordance with the stated codes and standards guidelines	N/A	No testing details in this code and standard applicable to gantry structures. But weld testing of the fabrication is detailed in this code and standard. Gantry frame testing but will require supplemental.											
				Entire	Ball-Screws				This code and standard gives no testing but will require supplemental.										
		Gear boxes	ASME NOG-1	Section 5150	Critical Items														
				Sections 5413 & 5416	Single Failure Proof features and gearing	Selection in accordance with the stated codes and standards guidelines	N/A	No testing details in this code and standard applicable to gantry structures. But weld testing of the fabrication is detailed in this code and standard. Gantry frame testing but will require supplemental.											
			ANSI N14.6	Entire															
				Section 5150	Critical Items														
		Motors	ASME NOG-1	Section 5150	Critical Items														
				Section 5412 & 5416	Single Failure Proof features and Drive motors	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard											
			ASME NOG-1	Section 5150	Critical Items														
				Section 5414 and 5416	Single Failure Proof features and Brakes	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard											
		Lift system Brakes	ASME NOG-1	Section 5150	Critical Items														
				Sections 5416, 5454 and B5476	Single Failure Proof features and Drive shafts	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard											
			ASME NOG-1	Section 5150	Critical Items														
				Section 5411, 5416 and 5451	Single Failure Proof features and Components and couplings	Selection in accordance with the stated codes and standards guidelines	N/A	No applicable testing details in this code and standard											
Gantry Lifting Control System	ASME NOG-1	Section 6440 including B442, B443, B444 and B445	Limit Switches, including, High, Low, Overspeed and Host Load Limit																
		Section 6410 and 6331	Controllers and Host speed	Selection in accordance with the stated codes and standards guidelines															

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Table A-1. Appendix A (Continued)

SDD ITS Requirements & Engineering Solutions			Code and Standard Applicability						Supplemental Requirements				Design Development Requirements				Remarks
Requirement Number	Requirement Text	Applicable SSCs	Code or Standard (see section 6 for definitions)	Applicable Section	Section Description	Req'd Calculation	Req'd Modeling	Req'd Testing	Additional Criteria	Req'd Drawings or Calculation	Req'd Modeling	Req'd Testing	Req'd Analysis	Req'd Drawings or Calculations	Req'd Modeling	Req'd Testing	
7.8	In the event of a credible fire in an area where waste forms are present, the temperature of machinery that handles or transports SNF/HLW shall not reach a level that would make it drop its load. (Reference, Nuclear Safety Design Basis for Licence Application, 000-30R-MGR0-00400-000-001 c, Appendix A table A-1f).	Lift system Brakes	ASME NOG-1	Section 5150	Critical Items	Selection in accordance with the code and stated codes and standards guidelines	N/A	No applicable testing details in this code and standard	Selection of components with a reliable nuclear pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
				Section 5414 and 5416	Single Failure Proof features and Brakes												
		Drive Brakes	ASME NOG-1	Section 5443	Bridge Brakes	Design calculations in accordance with the code and standard to verify conformance	N/A	No applicable testing details in this code and standard	Selection of components with a reliable nuclear pedigree and selection calculations to suppliers information and see section 8.1 for details	N/A	N/A	Factory acceptance testing. This testing could be included with DDP testing for requirement 4	N/A	N/A	N/A	N/A	
7.9	A tipover and breach of a Waste Package while on machinery that handles or transports SNF/HLW due to uncontrolled movements produced by a loss of power or a spurious signal caused by a fire shall have a probability of less than $1 \times 10^{-6}$ over the life of the facility. (Reference, Nuclear Safety Design Basis for Licence Application, 000-30R-MGR0-00400-000-001 c, Appendix A table A-1f)	Fire Protection System	NFPA	NFPA	NFPA	Calculations for adequacy of the system to deal with a credible fire	N/A	Fire detection and suppression system testing (see section 8.6)	Selection of components with a reliable nuclear pedigree and suitability for use in the required environmental conditions see section 8.8 for details	Gantry Fire protection layout assembly drawing	N/A	Testing to confirm performance of the detection and suppression system	N/A	N/A	N/A	N/A	
																	The prototype testing will include the whole gantry assembly. Therefore by default all individual ITS SSCs will be subject to prototype testing to ensure reliability.
		All SSCs below	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Control system performance testing to confirm operational requirements are achieved (See also section 9.1)	FMEA, and Fault Tree Analysis	Gantry general assembly drawing	N/A	Prototype testing	The Gantry control system is not ITS because the lift and travel drives will both contain powered off braking systems. Upon loss of power the brakes in both systems will be automatically applied. Upon recovery of power the brakes will require to be manually reset to disengage them.
		Lift and Linear Drive control system	ASME NOG-1 See remarks	Section 6410 and 6331	Controllers and Hoist speed	Design calculations in accordance with the code and standard to verify conformance	N/A	No applicable testing details in this code and standard	Selection of components with a reliable nuclear pedigree see section 8.1 for details	Performance speed and speed tolerance calculations required in accordance to the code and standard	N/A	Control system performance testing to confirm operational requirements are achieved (See also section 9.1)	N/A	N/A	N/A	N/A	
		Fire protection system	NFPA	NFPA	NFPA	Calculations for adequacy of the system to deal with a credible fire	N/A	No applicable testing details in this code and standard	Selection of components with a reliable nuclear pedigree see section 8.1 for details	Gantry Fire protection layout assembly drawing	N/A	Testing to confirm performance of the detection and suppression system	N/A	N/A	N/A	N/A	

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